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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Atmospheric Infrared Sounder

Tropospheric Transport

with

AIRS CO2 , O3 Retrievals

Working in the partial ∂erivatives domain

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Qinbin Li
Yuk Yung (CIT)
(James Randerson UCI)

AIRS Science Team Meeting
Greenbelt MD
Thursday September 28, 2006

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GEOPHYSICAL RESEARCH LETTERS, VOL. 33, L14814, doi:10.1029/2006GL026141, 2006

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CO_2 in the upper troposphere: Influence of stratosphere-troposphere exchange

Run-Lie Shia,[1] Mao-Chang Liang,[1] Charles E. Miller,[2] and Yuk L. Yung[1]

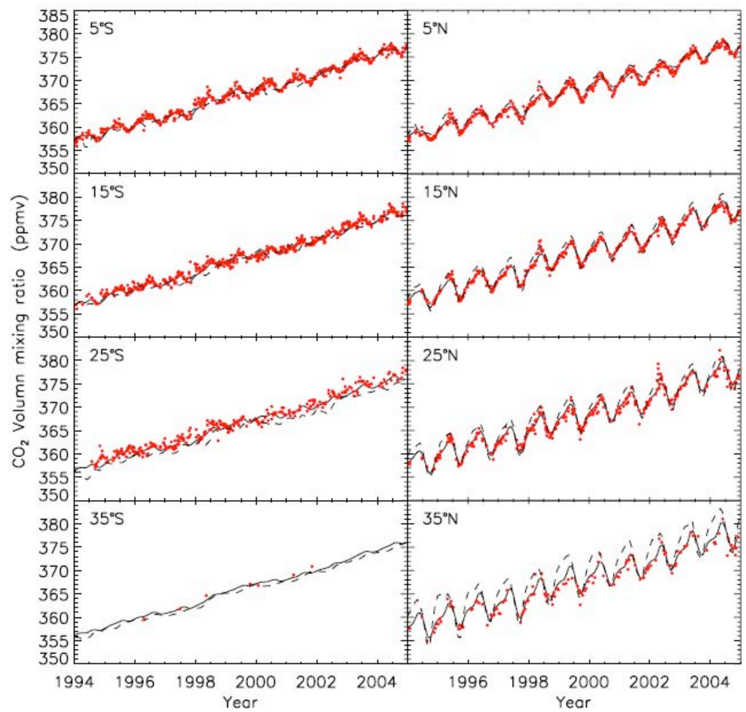
Received 24 February 2006; revised 19 May 2006; accepted 5 June 2006; published 26 July 2006.

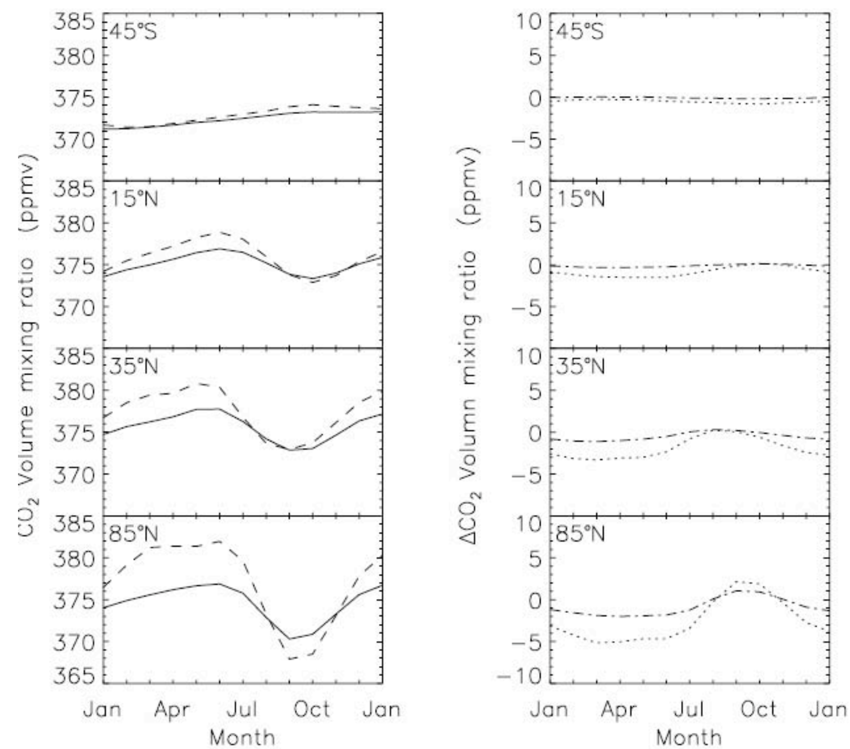
[1] A two-dimensional transport model constrained to measured surface CO_2 concentrations was used to simulate the spatial and temporal variation of CO_2 in the atmosphere for the period from 1975 to 2004. We find that the amplitude, phase and shape of the CO_2 seasonal cycle vary as a function of both altitude and latitude. Cross tropopause exchanges, especially the downward branch of the Brewer-Dobson circulation, which brings stratospheric air to the upper troposphere at middle and high latitudes, change the CO_2 concentration and seasonal cycle in the extra-tropics. The model results match recent aircraft measurements of CO_2 in the upper troposphere (*Matsueda et al.*, 2002) remarkably well. We conclude that upper tropospheric CO_2 volume mixing ratios will provide a valuable tool for validating vertical transport. The implications of the CO_2 variation caused by the stratosphere-troposphere exchange for remote sensing of CO_2 are discussed. **Citation:** Shia, R.-L., M.-C. Liang, C. E. Miller, and Y. L. Yung (2006), CO_2 in the upper troposphere: Influence of stratosphere-troposphere exchange, *Geophys. Res. Lett.*, *33*, L14814, doi:10.1029/2006GL026141.

significantly to this difference because this portion of the column constitutes approximately 20% of the column air mass and the CO_2 mixing ratio in this region can differ by 5 ppmv or more from the CO_2 mixing ratio at the surface [*Anderson et al.*, 1996; *Matsueda et al.*, 2002]. Since CO_2 is inert in the atmosphere, its trend and seasonal cycle propagate primarily from the surface. The difference of CO_2 mixing ratios between the surface and a given altitude is determined by the processes that transport surface air throughout the atmosphere, including advection, convection and eddy mixing.

[4] In the extra-tropics of the upper troposphere during winter, the CO_2 concentration is particularly influenced by the air descending from the lower stratosphere in the downward branch of the Brewer-Dobson circulation. The CO_2 mixing ratio is lower and the seasonal cycle is different in the stratosphere because it takes more than 1 year to transport surface air to the stratosphere through the tropical pipe [*Plumb and Ko*, 1992; *Plumb*, 1996] and the original seasonal cycle from the surface is diluted [*Mote et al.*, 1996]. Earlier studies of nitrous oxide demonstrate the influence of

CO2 Mixing Ratio - Transports





Matsueda Aircraft Flasks

Model (GEOS CHEM)

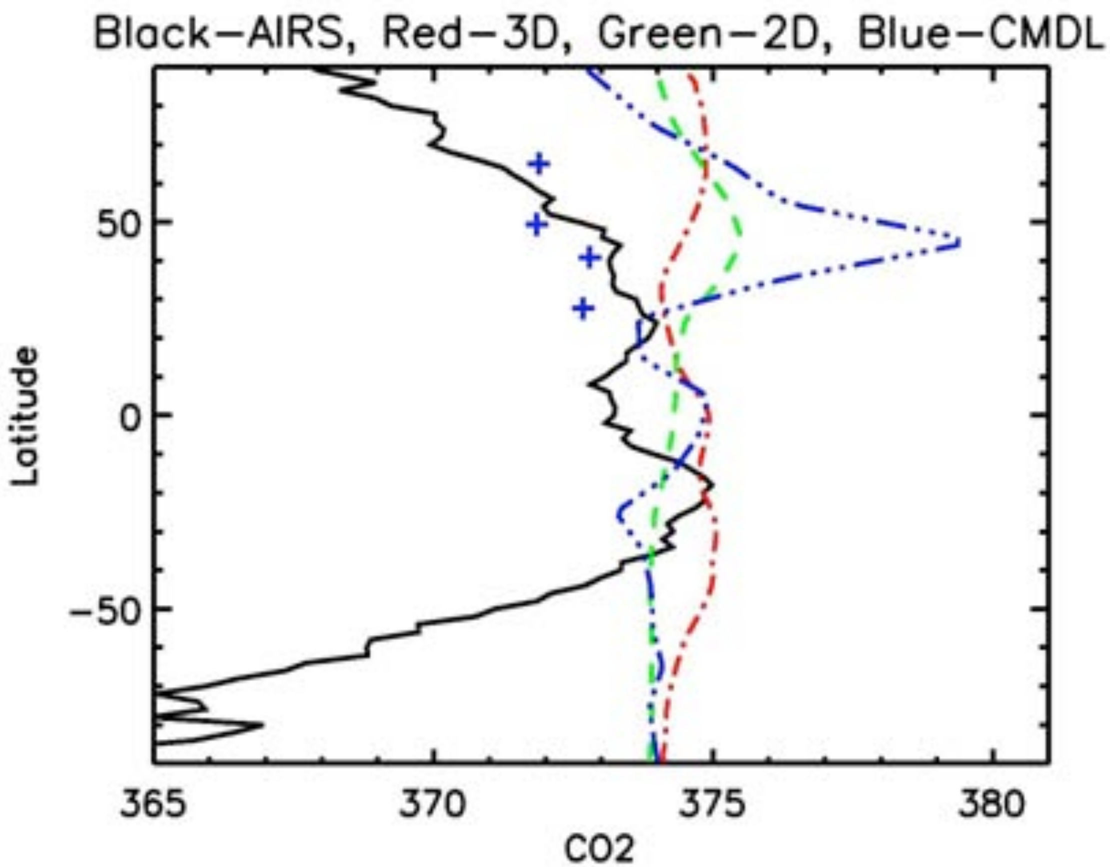
Surface Measurements
(Tans et al.1998)

Model Column Average

Model Surface mixing Ratio

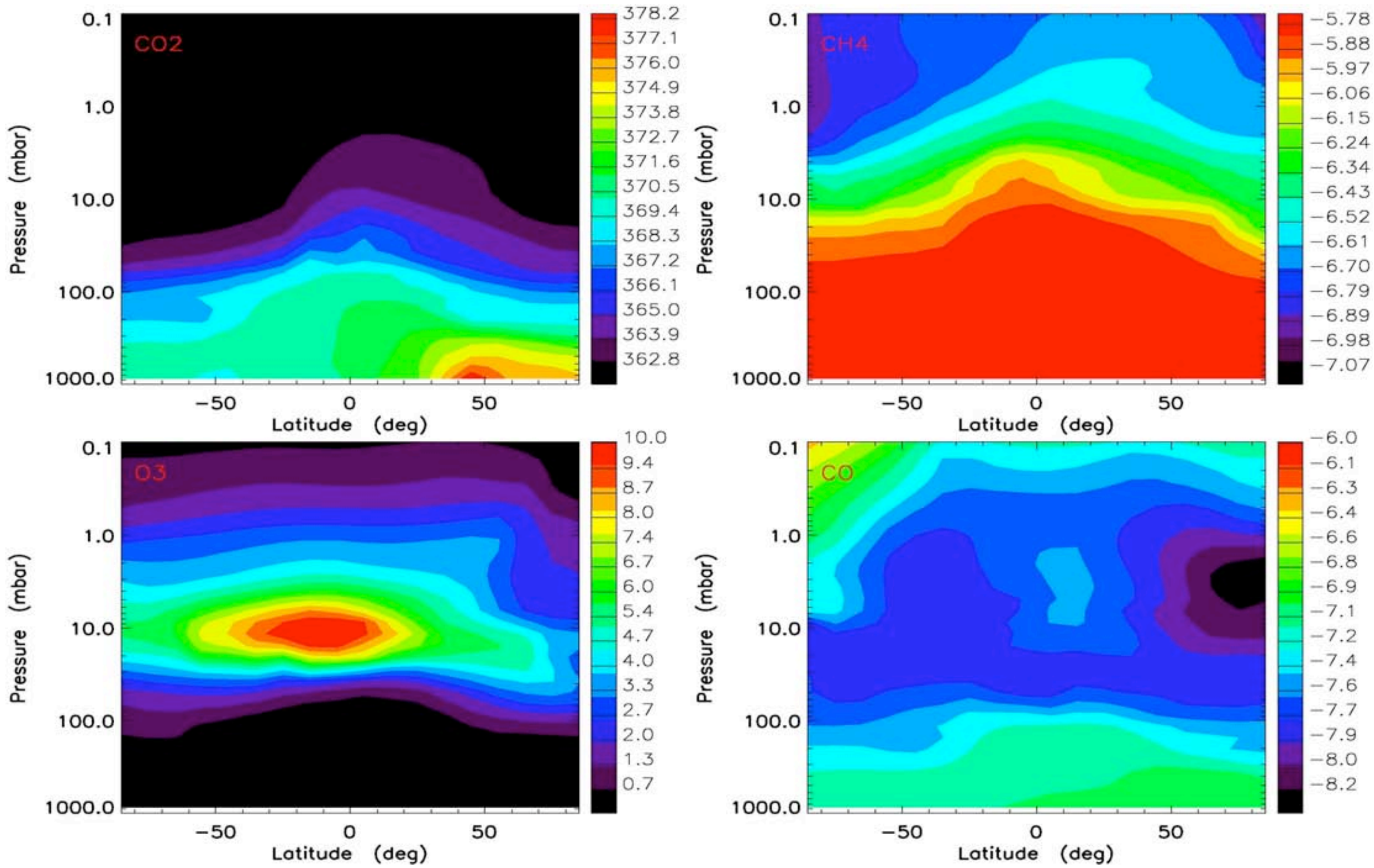
Difference

1-7 October, 2003



+ CMDL 300-500mb — · · — · · · CMDL Surface

GEOS-CHEM 3D Model



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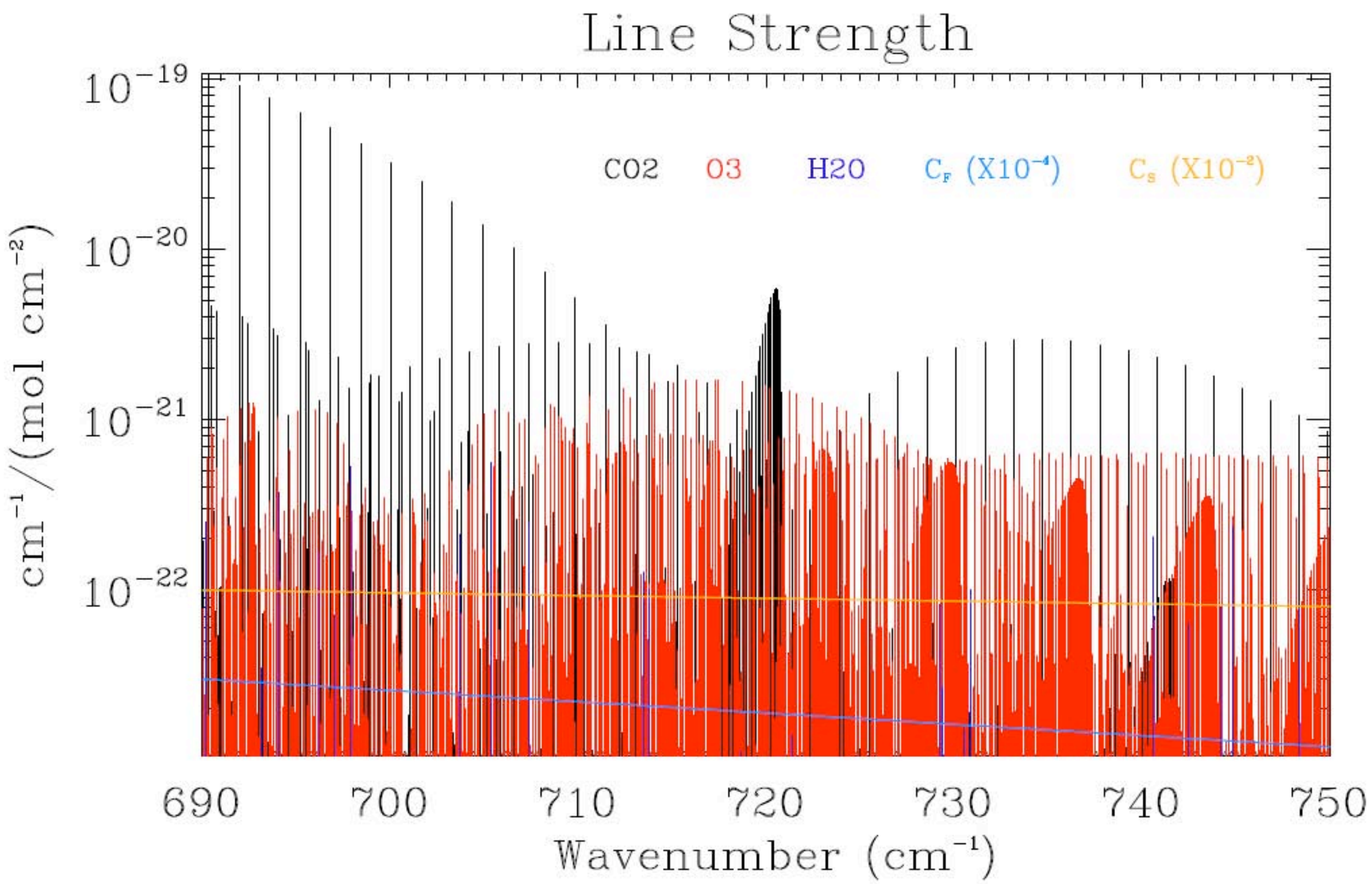

C_s and C_f are the self and foreign component of the continuum absorption in 1/(cm-1 molecules cm-2)

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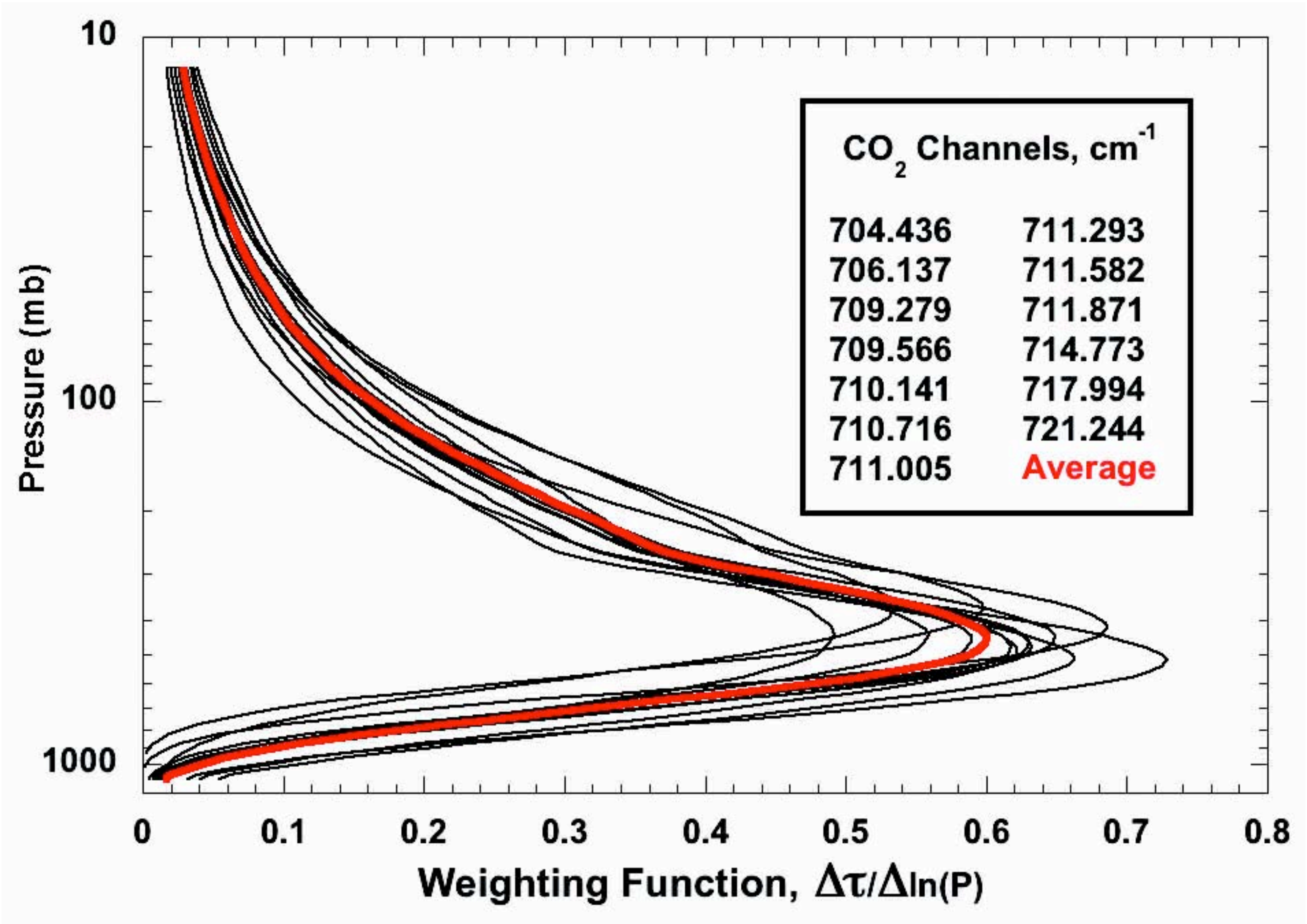
CO_2 Sounding Channels Individual Weighting Functions



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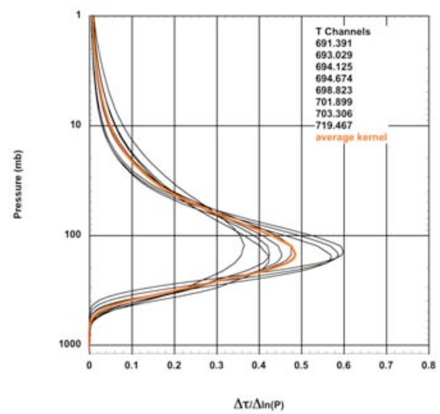
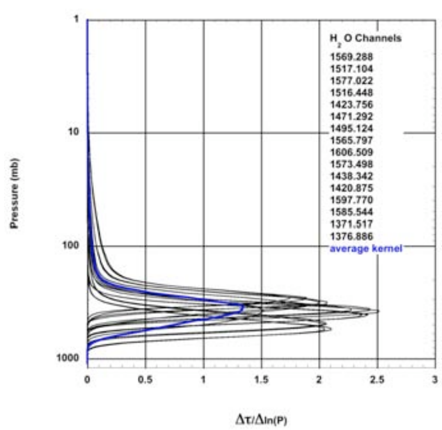
Atmospheric Infrared Sounder

Auxiliary Sounding Channels Individual Weighting Functions

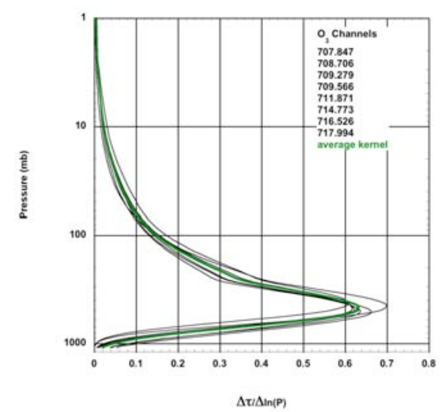
Temperature



Water vapor



Ozone



Vanishing Partial Derivatives (VPD)

In GRL, November 18, 2005

We consider the case where observations are made in a spectral region in the infrared where several minor gases such as CO_2, O_3, CO, CH_4 and SO_2 are radiatively active.

We define the residual function G **as**

$$G^{(n)} = \sum_{\nu} [\Theta_M(\nu) - \Theta_C^{(n)}(\nu)]^2 \qquad (2)$$

We aim to find the set of X_i **which minimizes the residual function. We express the total differential of** G **as**

.

$$dG = \frac{\partial G}{\partial X_1} dX_1 + \frac{\partial G}{\partial X_2} dX_2 + \frac{\partial G}{\partial X_3} dX_3 + ... + \frac{\partial G}{\partial X_i} dX_i + \varepsilon \qquad \textbf{(3)}$$

From the general property of total differentials, the condition that *G* in equation (2)

should have a **maximum or a minimum at a point** ($\bar{X}_i^{(1)}, \bar{X}_2^{(1)}, \bar{X}_3^{(1)}, \bar{X}_i^{(1)}$) **is that**

each of the first partial derivatives should individually vanish at that point.

$$\frac{\partial G}{\partial X_1} = 0, \quad \frac{\partial G}{\partial X_2} = 0, \quad \frac{\partial G}{\partial X_3} = 0 \quad ,...., \quad \frac{\partial G}{\partial X_i} = 0 \qquad \textbf{(4)}$$

Thus we reach an important conclusion that the value of the individual mixing ratio of each of the minor gases is determined by the value that makes their first partial derivative, in equation (4), vanish individually. **Therefore, even though the observed spectra cannot differentiate between the individual lines, the partial differentials can!**

doi :10.1029/2005GL024165

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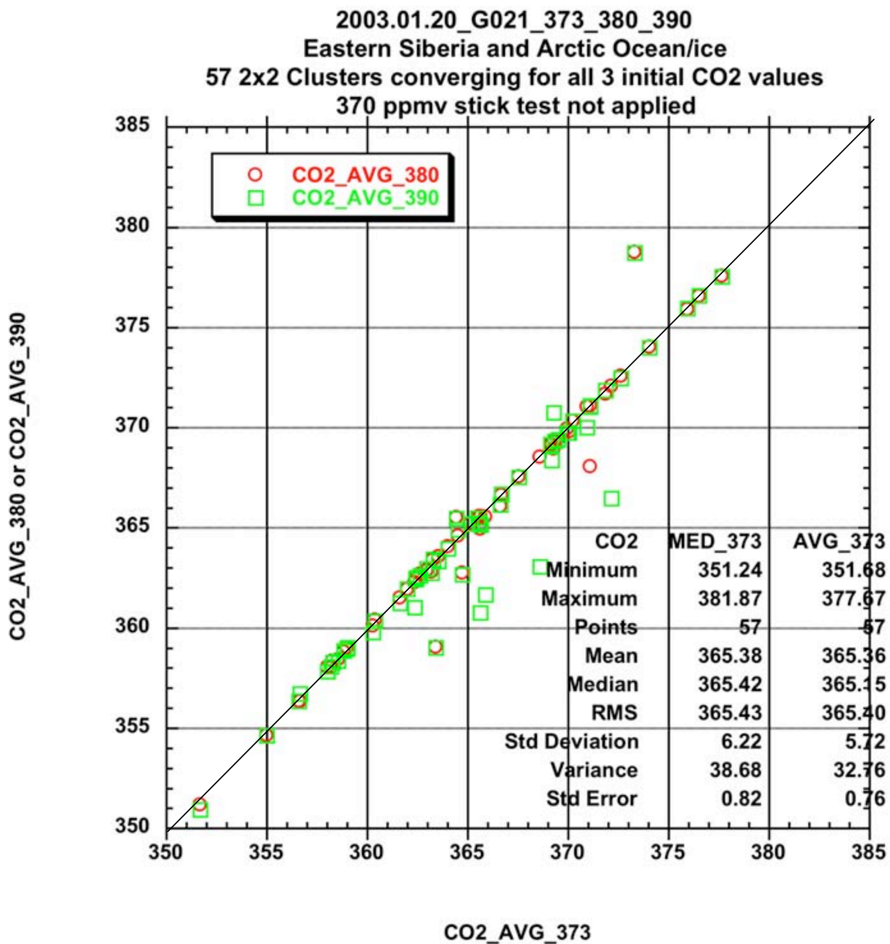
VPD Method
Independence of the solution
from Initial starting value of the CO2 Mixing Ratio

Vanishing
Partial
Derivatives
Method



Chahine, M., C. Barnet, E.T. Olsen, L. Chen, and E. Maddy, 2005: On the Determination of Atmospheric Minor gases by the Method of Vanishing Partial Derivatives with application to CO2, *Geophys. Res Lett.,* 32, L22803,doi: 10.1029/2005Gl024165

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Guassian (Uncorrelated) error By VPD

Total number of match ups= 78

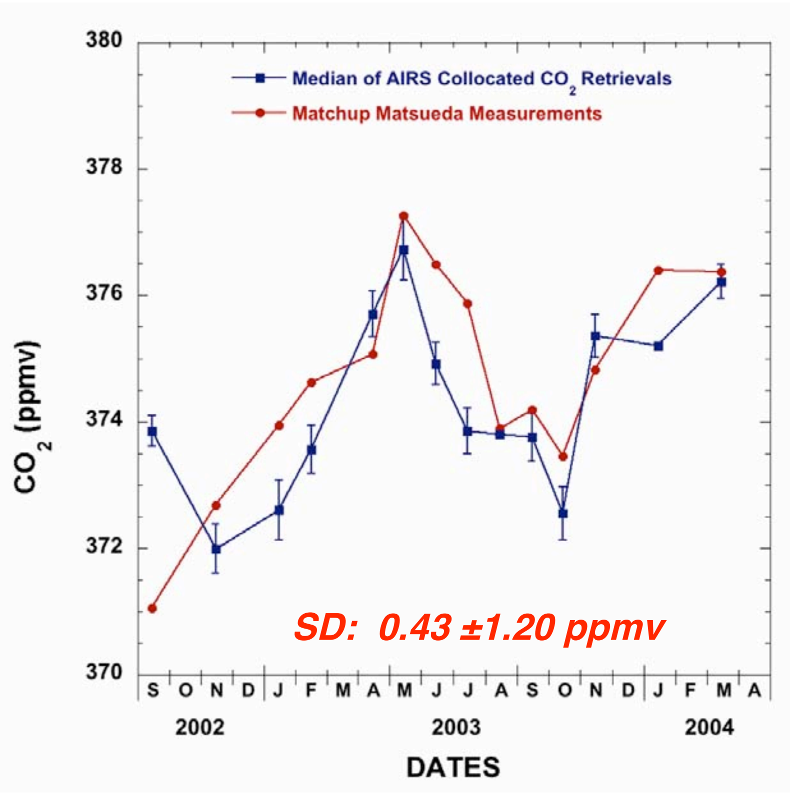
SD= ±2.98 *ppmv*

The monthly averages (5.6 clusters/month) yields

SD=±1.20 *ppmv*

These are approximately related by the Guassian relationship

$$\frac{2.98}{\sqrt{5.6}} = 1.26$$



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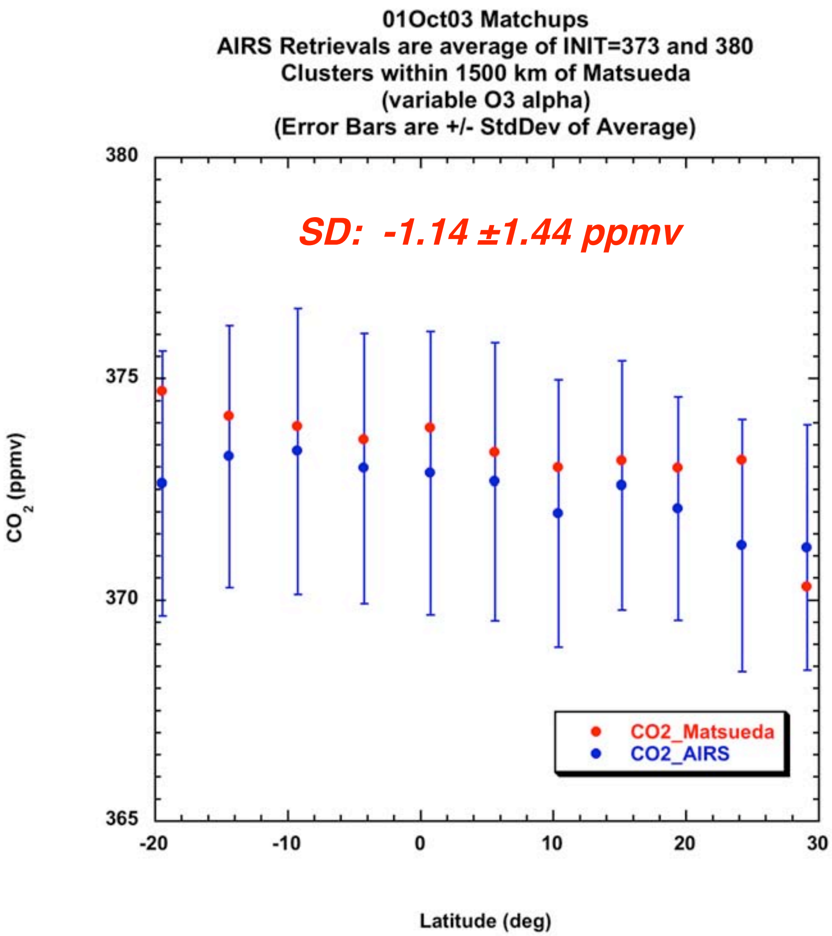
Comparison with Matsueda Daily Flask Measurements

October 1, 2003



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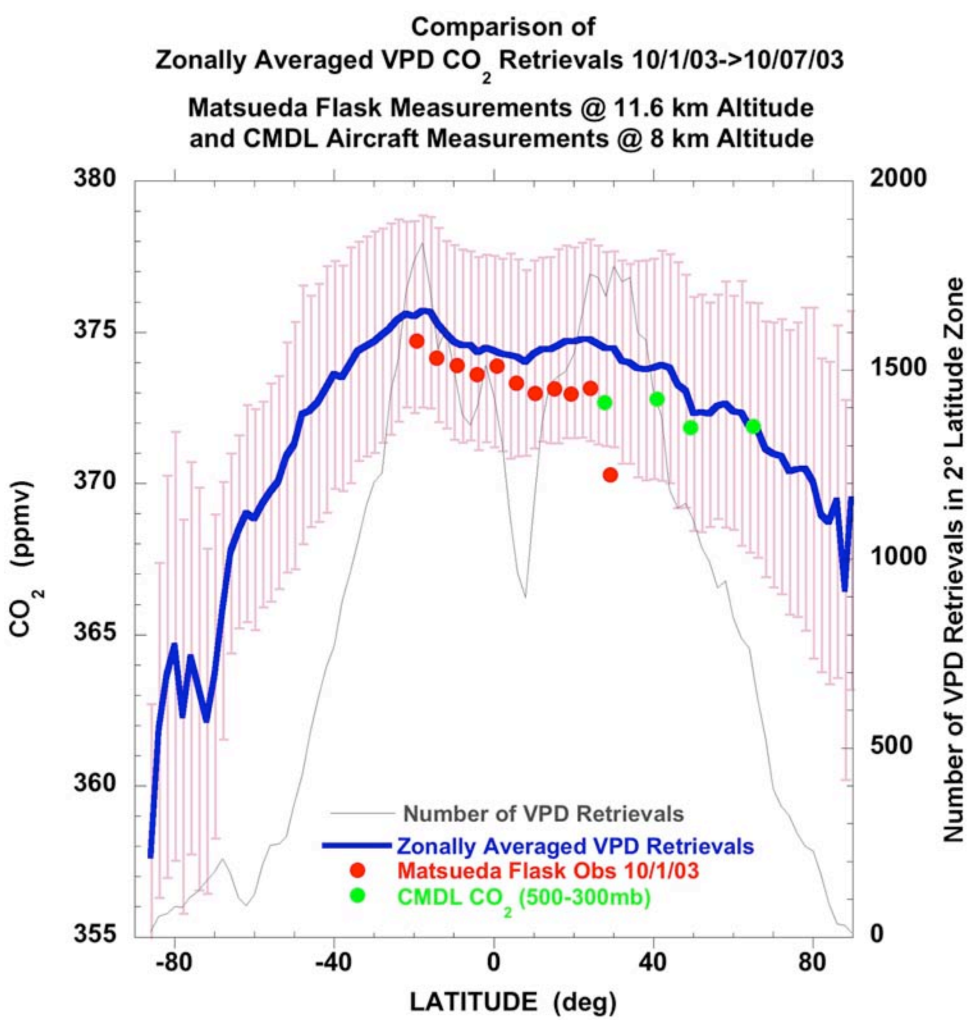
AIRS Zonaly Averaged CO_2

1-7 October, 2003



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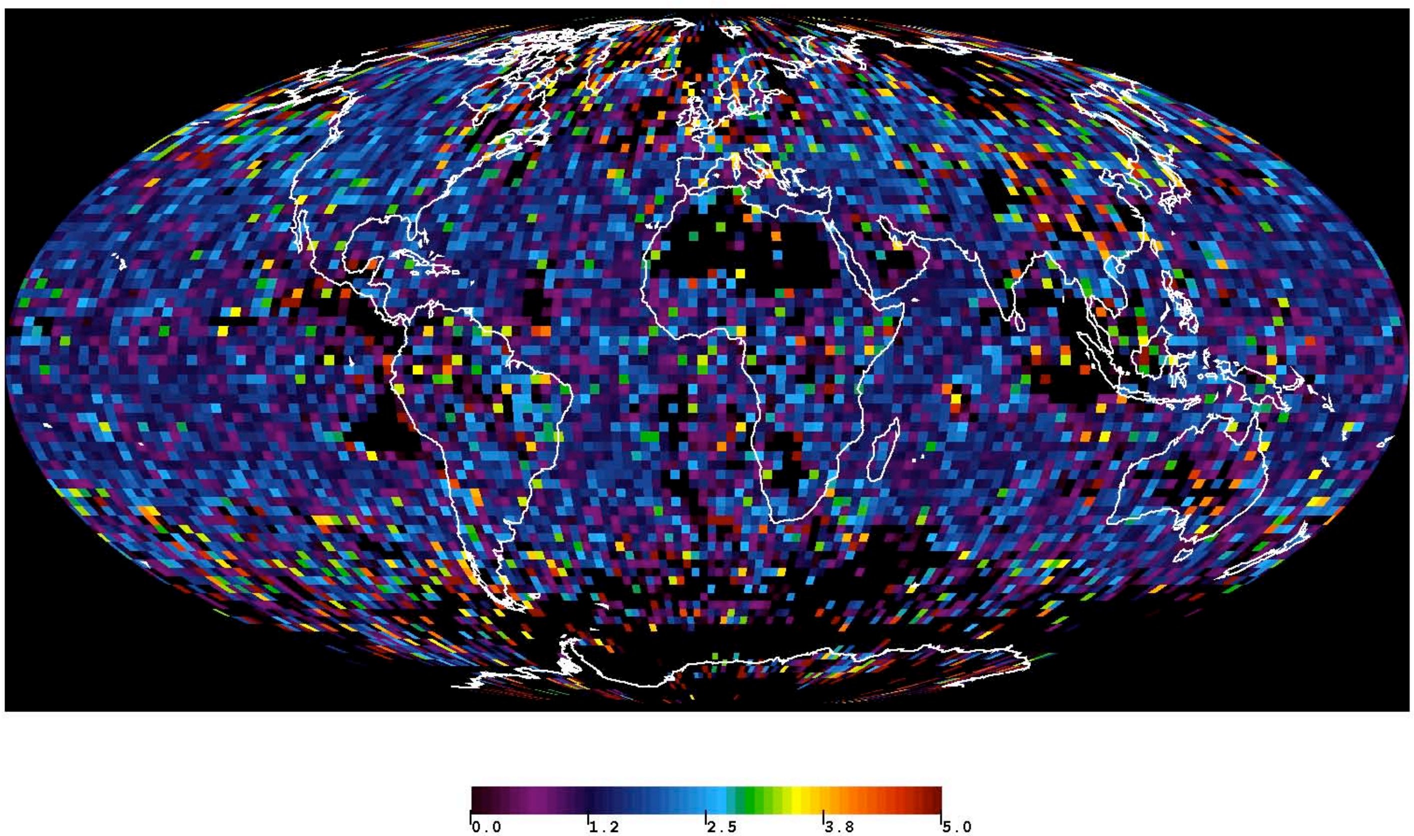
Error Covariance Matrix - CO2

1-7 October, 2003

AIRS CO2 STDEV (ppmv) FOR 2003.10.01 through 2003.10.07 BINNING: (2.50 X 2.00) CLIPPING: 1.0*STDEV



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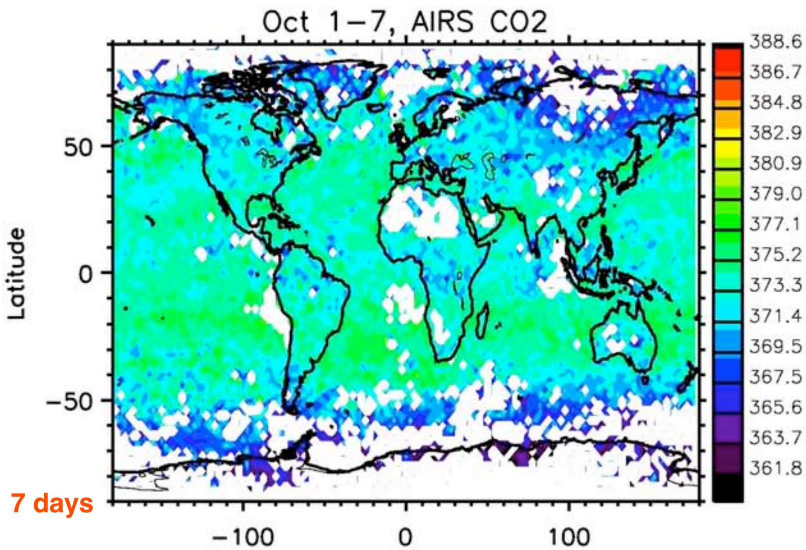
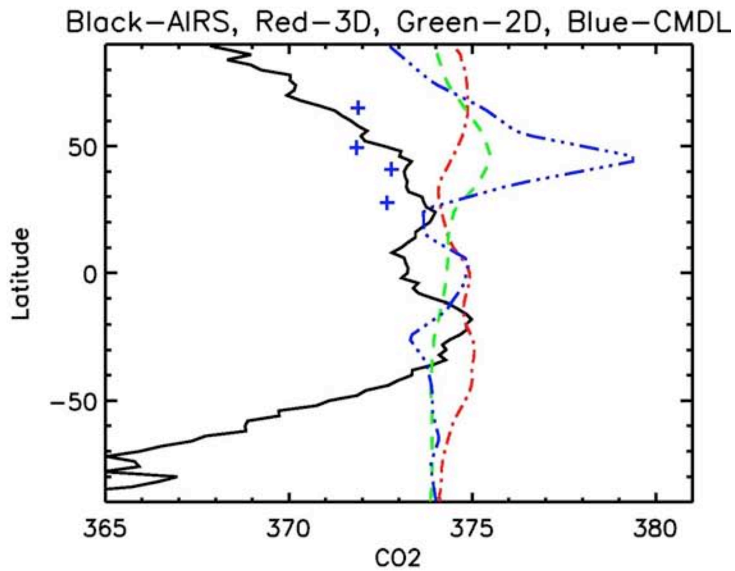
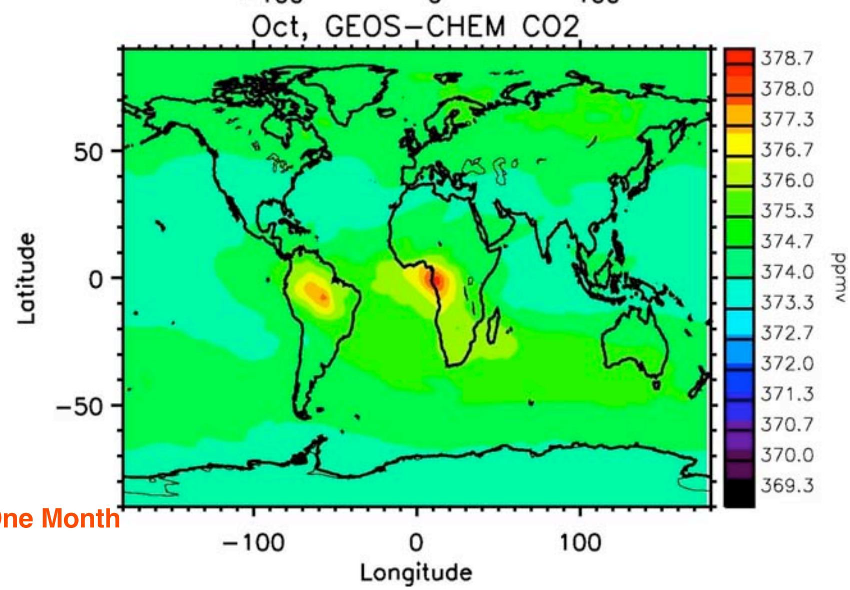
AIRS Global CO_2 Maps

1-7 October, 2003



7 days





One Month

CMDL Surface

\+ CMDL Aircraft 300-500mb

GEOS-CHEM 3D

Caltech/JPL 2D CTM

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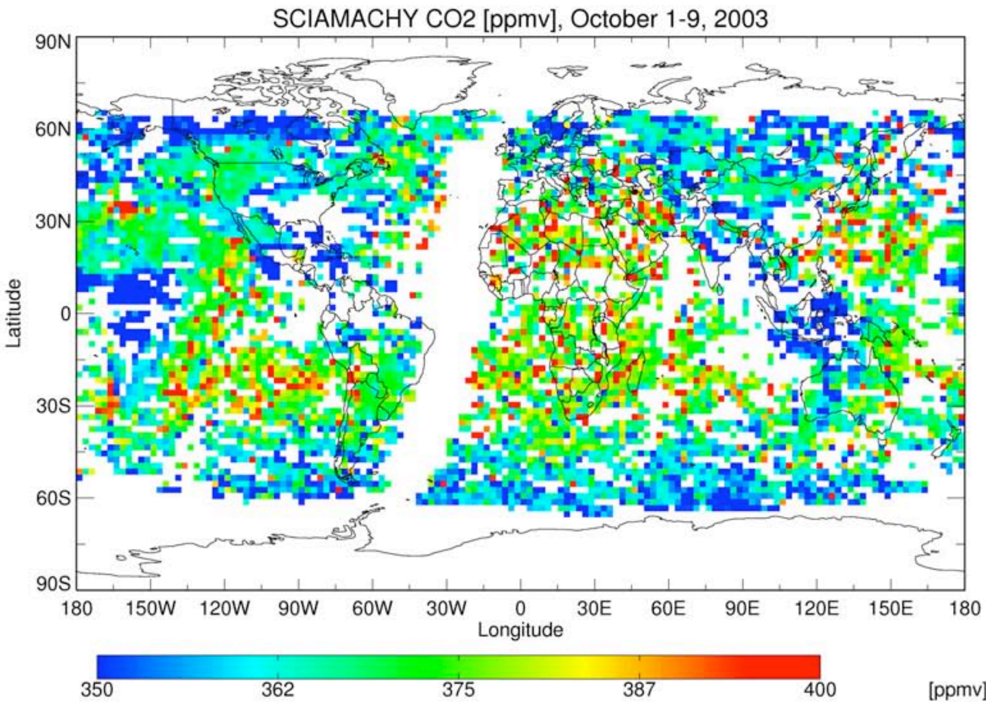
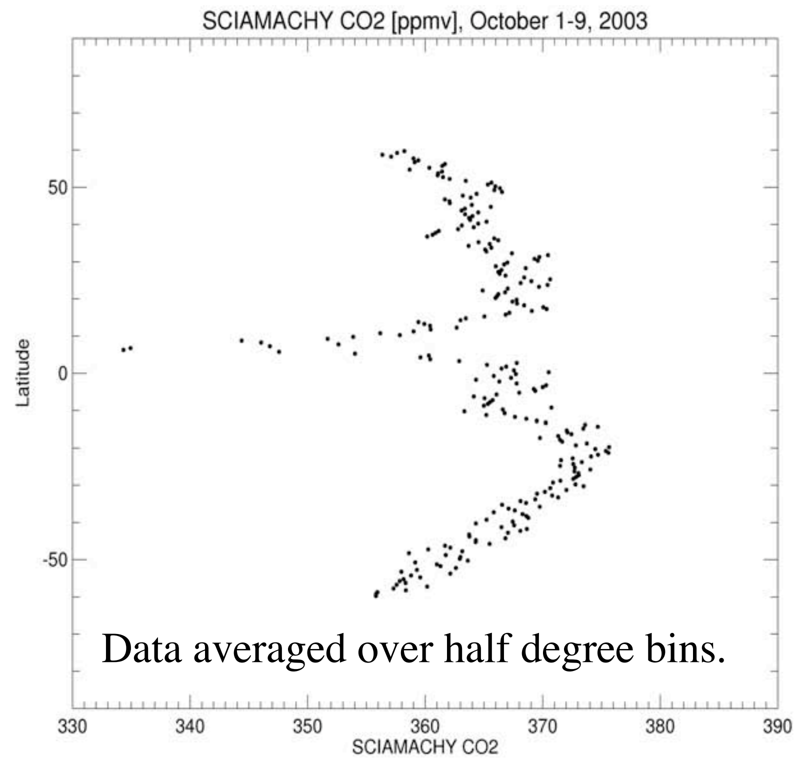
SCIAMACHY CO2, October 1-9, 2003

Atmospheric Infrared Sounder





Data averaged over half degree bins.

Data filtering criteria:

- Only forward scan pixels
- Cloud free
- XCO_2 error < 8%
- RMS < 0.007
- O_2 fit error < 1.8%
- SZA < 70.

SCIAMACHY CO_2 data version 0.4 provided by Michael Buchwitz.

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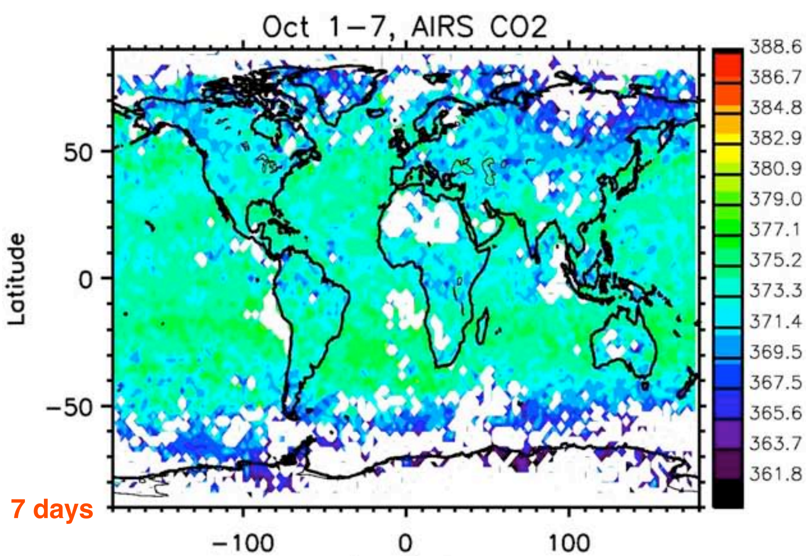
AIRS Global CO_2 Maps

1-7 October, 2003



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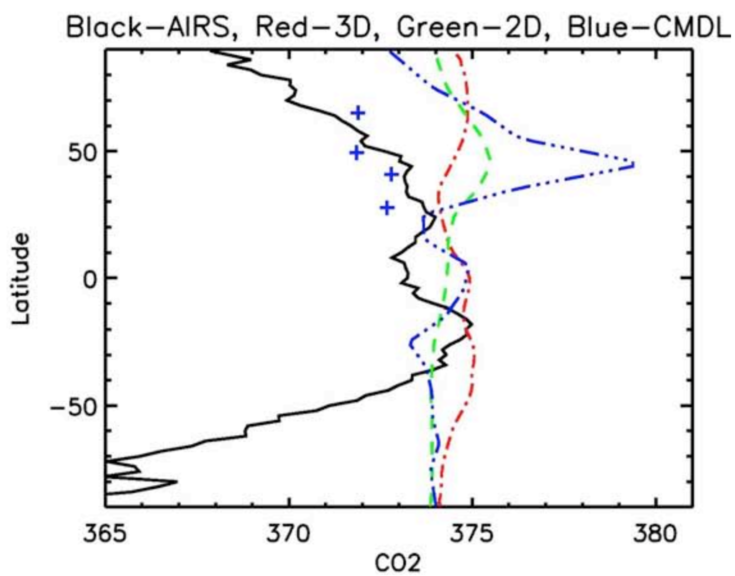
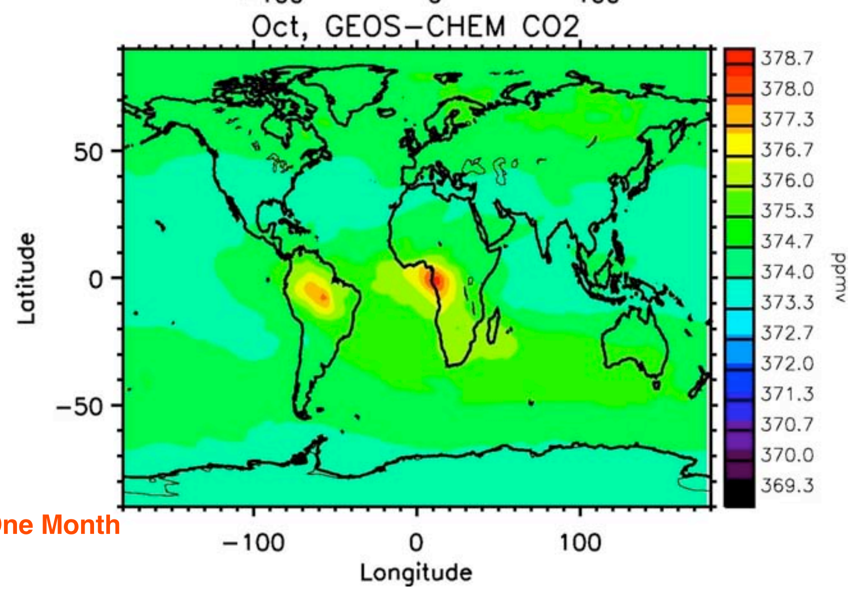
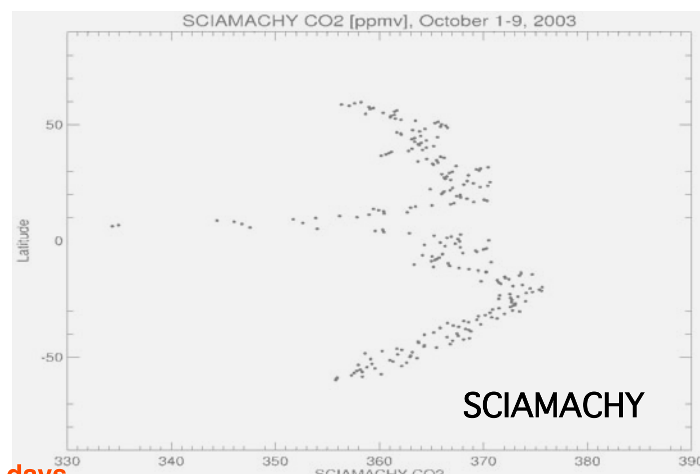




One Month



9 days

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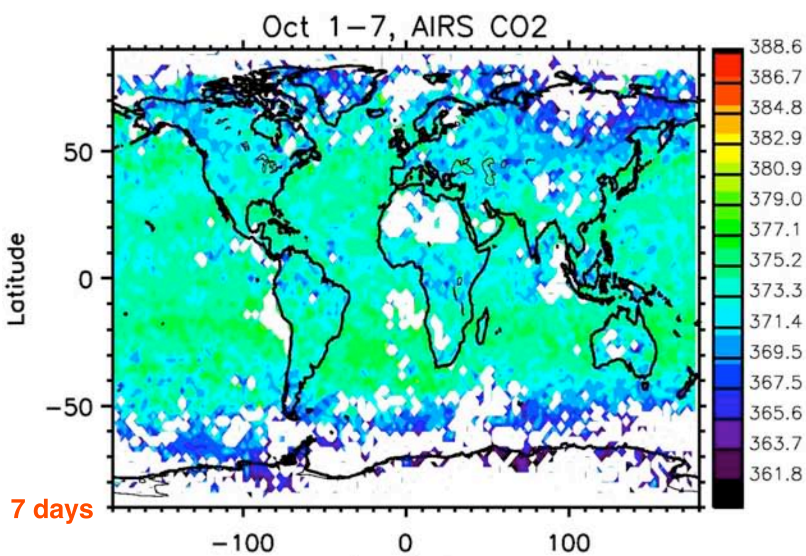
AIRS Global CO_2 Maps

1-7 October, 2003



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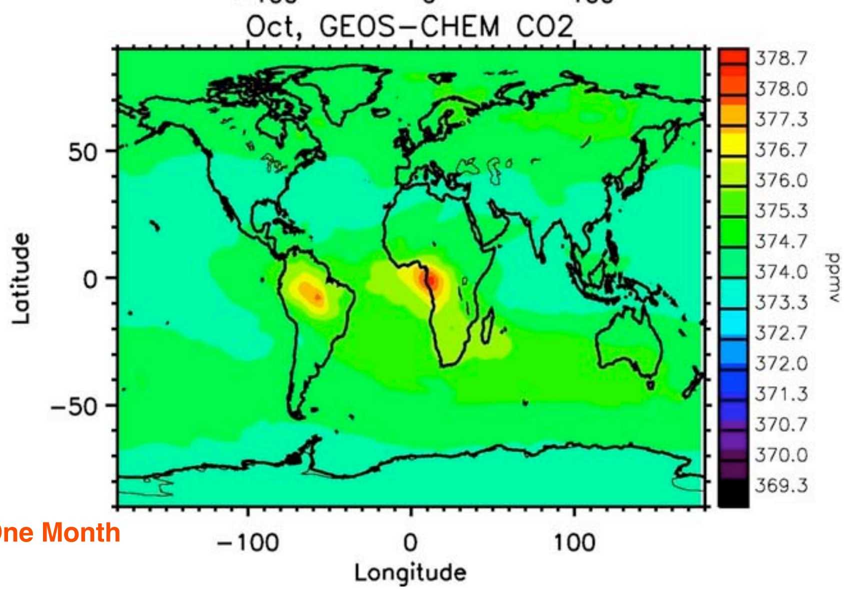
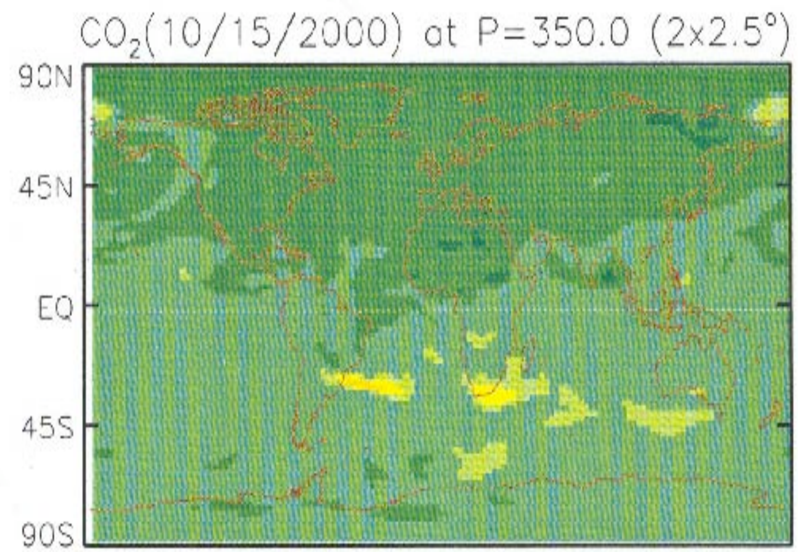


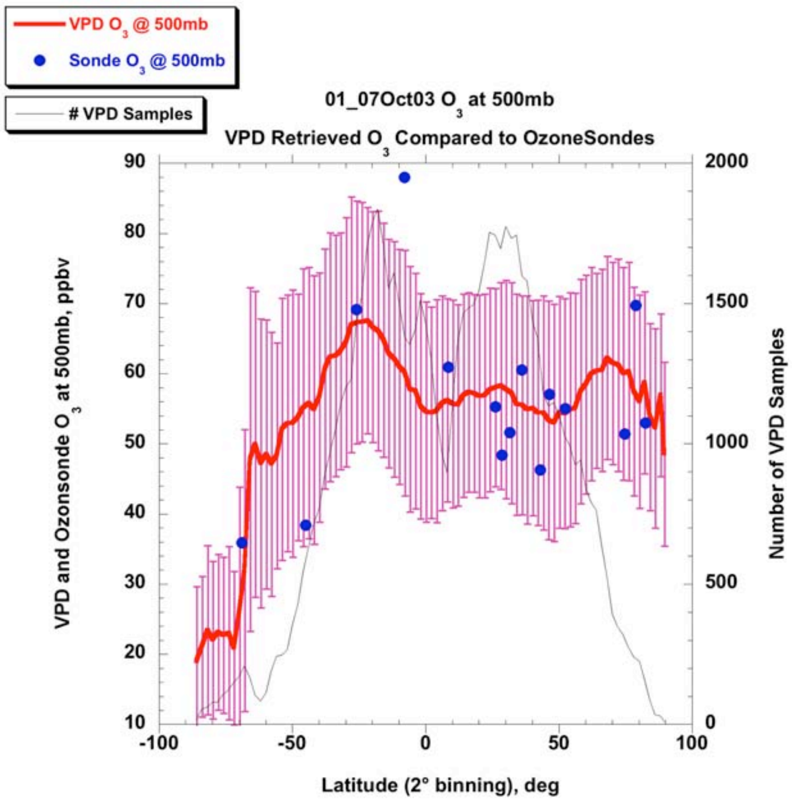
One Month

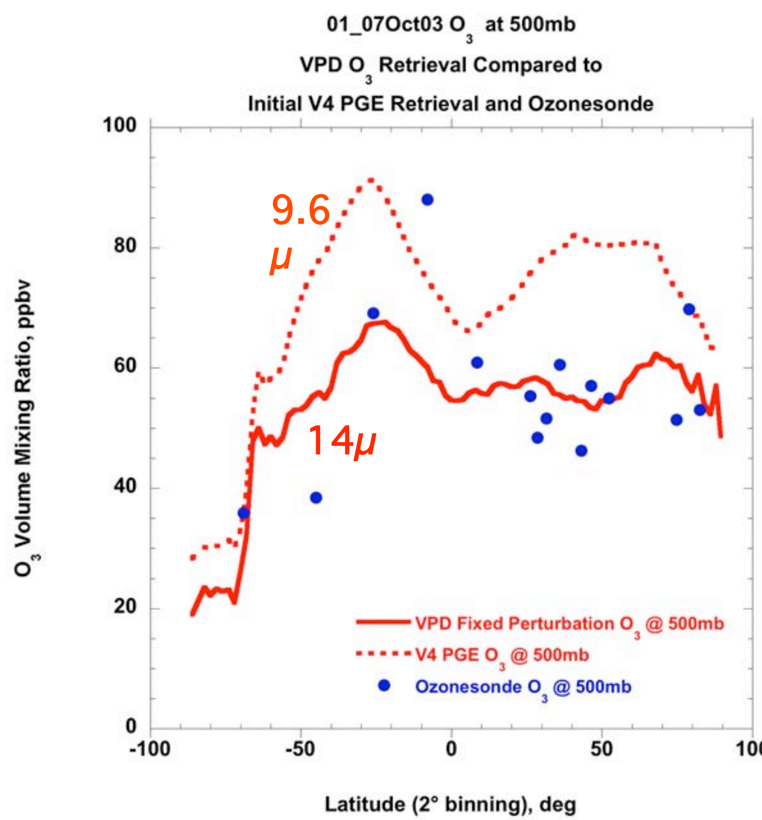


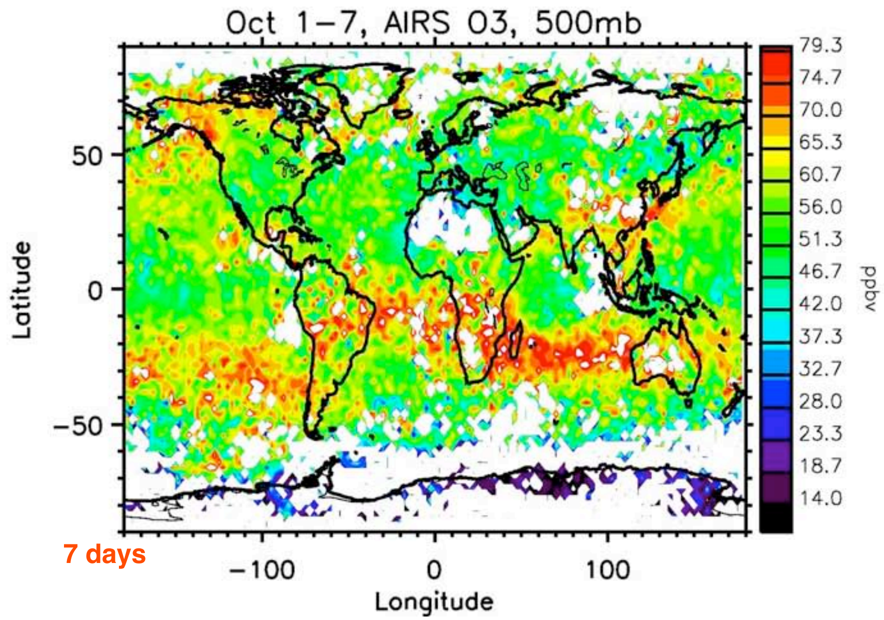
Kawa Oct 15, 2000

Tropospheric O3 –VPD Solution

500mb







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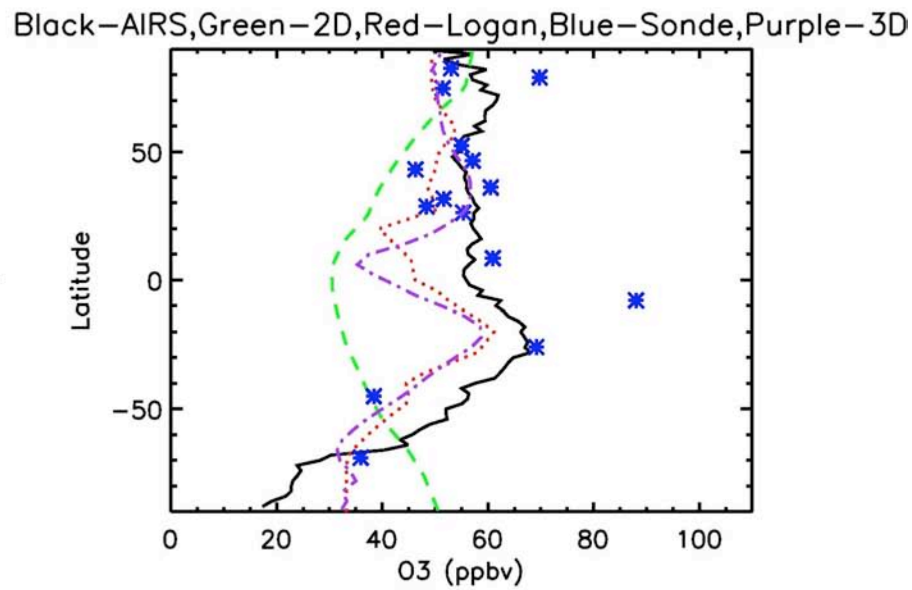
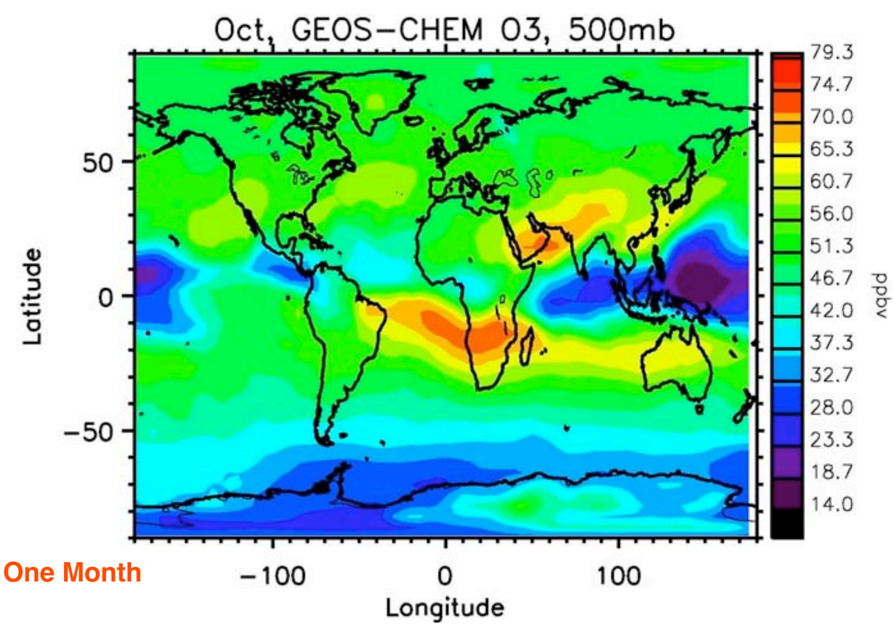




One Month

* Ozonesondes

AIRS

Caltech/JPL 2D CTM

GEOS-CHEM 3D

J. Logan Climatology

SUMMARY

The Vanishing Partial Derivatives method

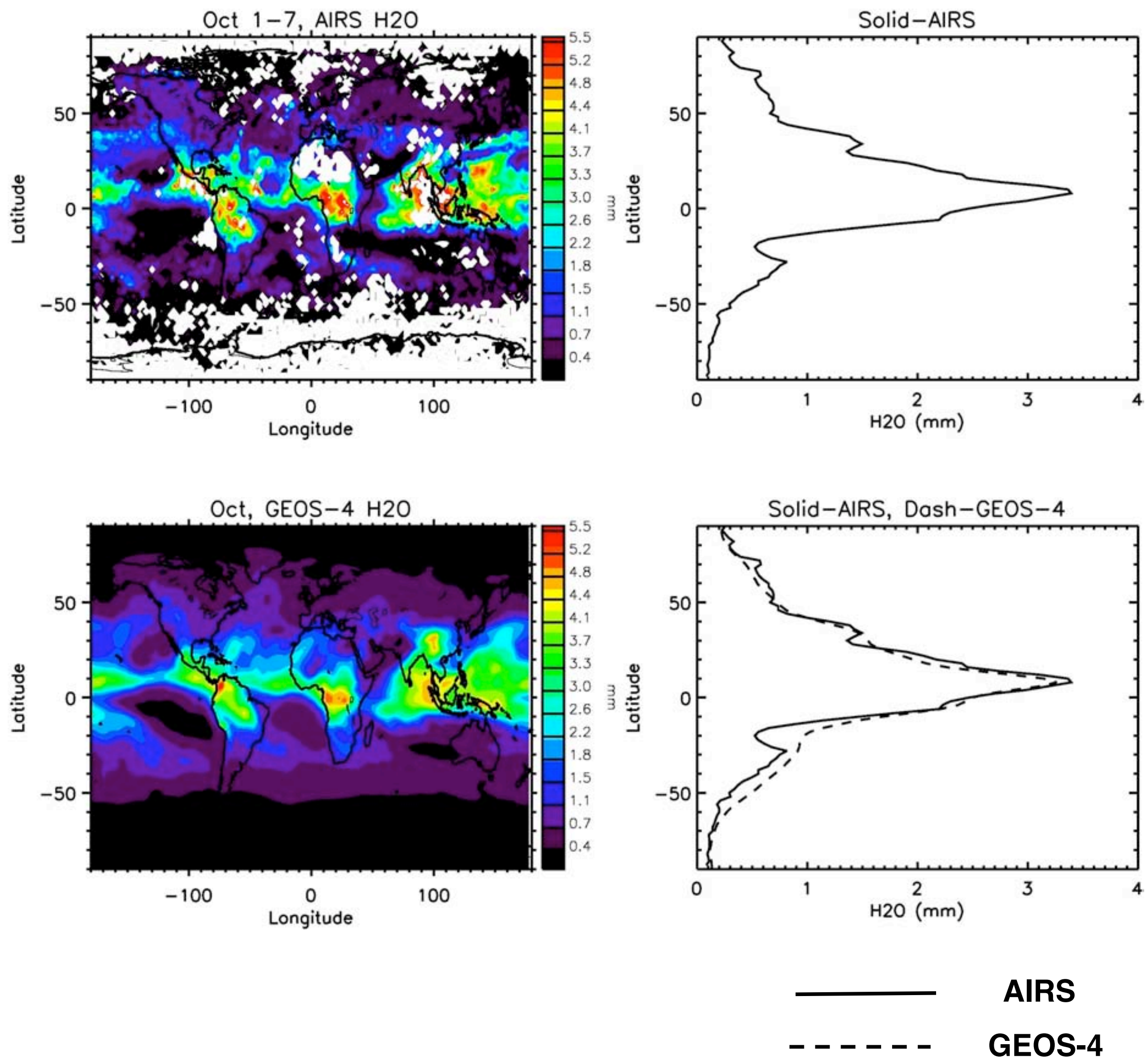
- Opens up new spectral regions for retrieval of tropospheric minor gases, even where pressure broadening tends to limits the usefulness of that spectral region
- Leads to accurate results, uncorrelated and independent of the background initial points

Future plans:

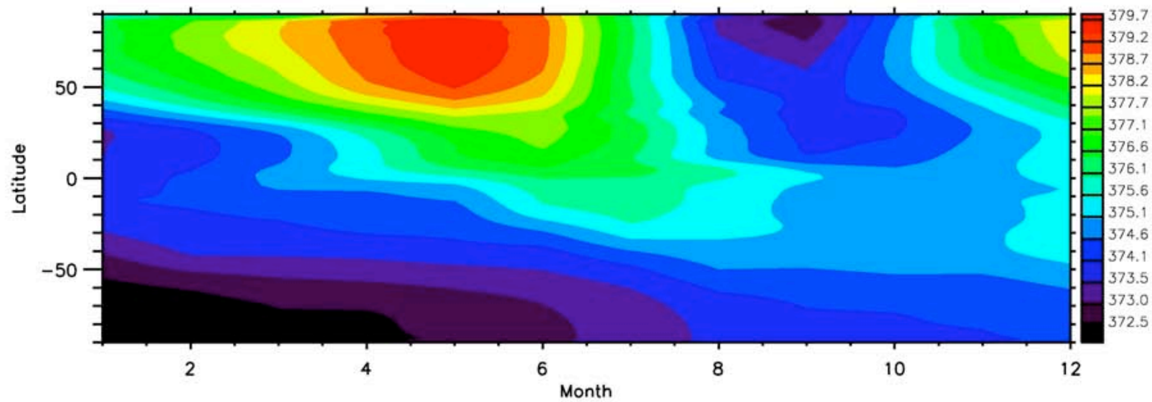
In 2007 we will apply the VPD method to resolve the boundary layer and retrieve H_2O, O_3 and CO_2 between the surface and 700mb.

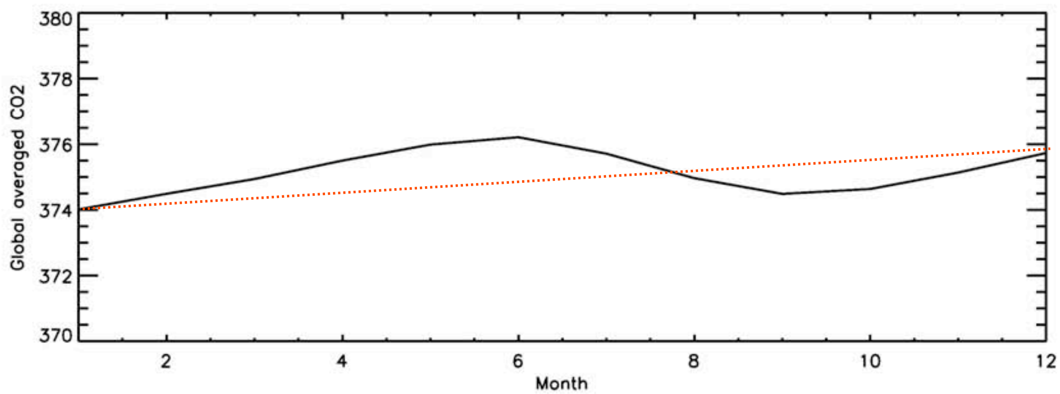
Thank you

Column Precipitable H2O above 500mb



GEOS-CHEM 2003





Xun Jiang

Sensitivity of the Auxiliary Ozone Channels